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4 CALIBRATION AND VERIFICATION

In this Chapter, the calibration/verification of three different regions is covered. First, the calibration and verification of the Everglades Agricultural Area (EAA) is presented followed by the calibration and verification of the Everglades and Lower East Coast (LEC). Lastly, the calibration of the lumped Lake Okeechobee Service Area (LOSA) basins is covered. Generally, calibration and verification is conducted on a limited data set of one to three years. However, in the C&SF Project, a 36-year period of record for modeling exists. As a result, lengthy calibration and verification periods can be established. Determining periods when few systems changes occurred and where hydrologic extremes exist are important considerations in addition to the normal concerns for data integrity.

Prior to model calibration and verification, an extensive quality assurance/quality control (QA/QC) check of all stage and flow data was conducted. Personnel from three South Florida Water Management District (SFWMD or District) departments were involved in the review. The QA/QC included statistical analyses, comparative analyses, flagging of data known to be impacted by unusual local events (e.g. drawdown tests), and an update of flow data where stage-flow relationships were improved.

Calibration, as applied to the South Florida Water Management Model (SFWMM), is the process by which model parameters are changed until a reasonable match between model output, primarily stage and discharge, and observed data is achieved. In this context, calibration can be more appropriately called history matching (Konikow and Bredehoeft, 1992). Model calibration relates to the assumption that a well calibrated model enhances its predictive capability. Verification is the process where the calibrated model parameters are used to predict hydrologic responses during periods where comparisons can be made to a different historical data set.

Due to the unique way by which the EAA is simulated in the model (refer to Section 3.2), only simulated runoff and demand volumes were compared with historical values. For the Everglades/LEC region, a set of water level monitoring/observation points and structure headwater stages were selected. Historical water level measurements at these locations and historical discharges through selected outlet structures were compared against stages and discharges simulated by the model, respectively. The calibration of the lumped LOSA basins is presented in the third section with flow comparisons to historical data.

The following guidelines, which apply to hydrologic models in general, were used in calibrating the model:

1. The availability of historical stage and flow data dictated the extent of the calibration period. Rainfall, the primary driving force in South Florida's hydrology, further limits the length of time by which historical and simulated stages and/or flows are to be compared. The period of comparison should include extremely wet and dry conditions.
2. The historical (field-measured) data set should be limited by what can be considered reliable. For example, the quality of historical data on discharges at some coastal structures was considered poor. Flows through these structures, which were normally considered as boundary conditions, were simulated when the model was run in

calibration mode. Therefore, after a field data verification process was conducted, graphical plots of simulated versus historical flow data were created.

3. The period of comparison should be short enough such that no significant changes in operational schemes occur in the middle of the simulation period. This assumption is important since most of the parameters used in the model are time invariant. As contrasted to succession models, a long-term simulation model such as the SFWMM has limited capability in making changes to certain operating parameters in the middle of a simulation run. For example, the policy of holding back more runoff in the EAA due to Best Management Practices (BMPs) has been implemented in the field only in the last few years. This policy also impacts Lake Okeechobee water release rules. Thus, calibration parameters could be markedly different depending on which years (pre-BMP vs. BMP) are emphasized.
4. The frequency by which available historical data was compared should be consistent with regional modeling space and time resolution. For the SFWMM, comparisons are typically done only on a monthly basis: monthly total discharges, end-of-month nodal stages and monthly mean canal levels. The succeeding discussions on calibration results will address space resolution and model discretization issues to some extent.
5. Display calibration results by plotting historical and simulated values on the same graph (e.g. clustered bar graphs for flow comparison, XY or scatter plots for stage comparison) and quantifying goodness-of-fit by using some statistical measures (e.g. r-squared, bias).

The scope of the entire SFWMM calibration process can be divided into three parts:

1. data update which includes time series (rainfall, reference ET, structure flows, stages at monitoring points and canals) and static data (land elevation, land use) updates;
2. computer program update which involves changes to existing subroutines and/or creation of new computer code, e.g., improvements to ET and overland flow algorithms; and
3. actual model calibration which requires accuracy checks on model algorithms, both old and new, and adjustments of model parameters that affect calculated water levels and discharges.

4.1 CALIBRATION OF THE EVERGLADES AGRICULTURAL AREA BASIN

The goal of the Everglades Agricultural Area calibration effort was to match, as closely as possible, supplemental irrigation requirements (demand) and drainage (runoff) in the EAA. As mentioned earlier, the calibration of the EAA was performed in a way that differs from the rest of the model. Simulated flow volumes, both supplemental irrigation requirement and runoff, were compared to historical volumes. Due to the lack of groundwater data throughout the EAA, limited matching of historical water levels, specifically in the Rotenberger area, was performed. This procedure may not be a serious shortcoming because stages in the highly irrigated EAA are maintained within a very narrow range (Abtew and Khanal, 1992).

4.1.1 Methodology

The EAA calibration period was from January 1984 to December 1995 and the verification covered two periods from January 1979 to December 1983 and January 1996 to December 2000. Version 5.5 of the SFWMM reflects the most up-to-date values of the calibration parameters.

Three parameters were adjusted during the EAA calibration: ET calibration coefficients **KCALIB**, and dimensionless local storage parameters **fracdph_min** and **fracdph_max** (refer to Section 3.2). Local storage parameters define the soil moisture level in the soil column at which runoff occurs and the level that triggers supplemental deliveries from other sources. All EAA calibration parameters vary monthly.

Since all parameters being adjusted were defined for each month, comparisons between historical and simulated monthly total long-term (averaged over calibration period) runoff and supplemental irrigation requirements were made. Runoff and supplemental irrigation requirements (which are mutually exclusive equations, i.e. one or the other is used) are defined as follows:

$$\text{Runoff} = \sum \text{structure outflows} - \sum \text{structure inflows} \quad (4.1.1.1)$$

$$\text{Supplemental Irrigation} = \sum \text{structure inflows} - \sum \text{structure outflows} \quad (4.1.1.2)$$

The general rules for adjusting EAA parameters are shown in Table 4.1.1.1.

Table 4.1.1.1 General Rules Used in Adjusting Calibration Parameters for the EAA in the SFWMM

Comparison of Runoff If simulated value is:	Comparison of Supplemental Irrigation If simulated value is:	Action
> Historical	< Historical	Increase ET calibration coefficient, KCALIB.
< Historical	> Historical	Decrease ET calibration coefficient, KCALIB.
> Historical	> Historical	Increase local storage (decrease soil moisture level triggering supplemental deliveries and/or increase soil moisture level triggering runoff).
< Historical	< Historical	Decrease local storage (increase soil moisture level triggering supplemental deliveries and/or decrease soil moisture level triggering runoff).

As mentioned in Section 3.2, the parameter KCALIB is used as an adjustment factor for a theoretical set of vegetation coefficients [KVEG in Equation (3.2.2.1)] determined from an earlier study (Abtew and Khanal, 1992). The limits on KCALIB (see Table 4.1.1.2) were established based on the desire not to alter the original values of KVEG significantly. The limits on parameters **fracdph_min** and **fracdph_max**, on the other hand, were established based on the

assumption that the mean soil moisture level, $[(\text{SOLCRNF} + \text{SOLCRT}) \div 2]$, does not vary substantially during the year. The final values of **fracdph_min** and **fracdph_max** are given in Table 4.1.1.3. The limits on soil moisture content, SOLCRT and SOLCRNF, can be calculated as the product of the assumed soil column depth (1.5 feet), the storage coefficient, and the limits on ratios **fracdph_min** and **fracdph_max**, respectively. SMAX and SMIN (for the Miami River Basin), in Figure 4.1.1.1 represent the limits on soil moisture content, expressed in terms of equivalent depths of water, in the unsaturated zone for a storage coefficient equal to 0.20.

The calibration parameters were adjusted until the mean monthly simulated and historical runoff and supplemental irrigation requirements (over the 1984-1995 time period) matched within about one percent.

Table 4.1.1.2 KCALIB Calibration Coefficients for Unrestricted Evapotranspiration in the EAA

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.500	0.615	0.840	0.650	0.840	1.055	0.630	0.675	0.575	0.500	0.570	0.505

Table 4.1.1.3 Final Values of Calibration Parameters (fracdph max and min) used for the EAA in the SFWMM v5.5

Month	Miami River Basin		North New River And Hillsboro Basins		West Palm Beach Basin	
	Max	Min	Max	Min	Max	Min
January	.2175	.0457	.1975	.0457	.1875	.0457
February	.1700	.0854	.1600	.0854	.1400	.0854
March	.2275	.0704	.2275	.0704	.2175	.0704
April	.2250	.0404	.2150	.0404	.2050	.0404
May	.5550	.0000	.5500	.0000	.5350	.0000
June	.2400	.0287	.2400	.0287	.2200	.0287
July	.2020	.0367	.1920	.0367	.1820	.0367
August	.2440	.0167	.2340	.0167	.2240	.0167
September	.1505	.0000	.1505	.0000	.1405	.0000
October	.1750	.0400	.1750	.0400	.1750	.0400
November	.1530	.0400	.1480	.0400	.1460	.0400
December	.1600	.0267	.1500	.0267	.1450	.0267

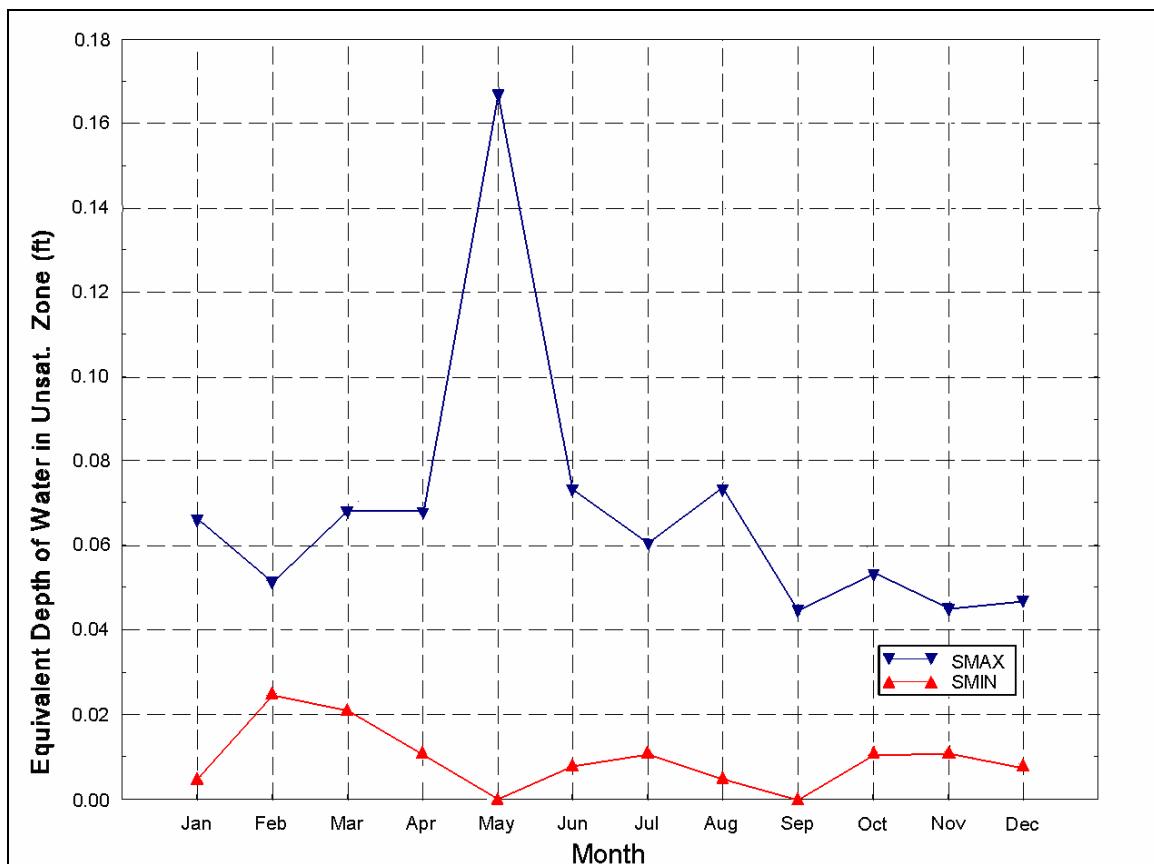


Figure 4.1.1.1 Miami River Basin Unsaturated Zone Storage Triggers for Runoff and Supplemental Flow as Implemented in the SFWMM

4.1.2 Everglades Agricultural Area Calibration and Verification Results

Time series plots comparing simulated and historical flow volumes for the entire EAA, and for each of the three sub-basins simulated by the model, were prepared. Both the calibration period and the verification period are presented. Annual volumes (Figures 4.1.2.1 and 4.1.2.2), daily flows (Figures 4.1.2.3 through 4.1.12), and monthly volumes and flows (Figures 4.1.2.13 through 4.1.2.18) were compared for the entire EAA. By plotting simulated versus historical values on the y- and x- axes, respectively, the goodness-of-fit for daily/monthly runoff and daily/monthly irrigation requirements can be evaluated (Figures 4.1.2.5 through 4.1.2.8 and Figures 4.1.2.17 through 4.1.2.20). A good fit is denoted by a regression line with a slope of unity and y-intercept at the origin.

Overall, differences between simulated and historical flow volumes can be attributed to a number of factors. They include:

1. errors in input data (static data, structure discharge, rainfall, etc.);
2. model inaccuracies due to model resolution (4-mile² grid cells, limited number of rainfall stations); and
3. oversimplified algorithm used to describe actual field-scale management of water by the farmers.

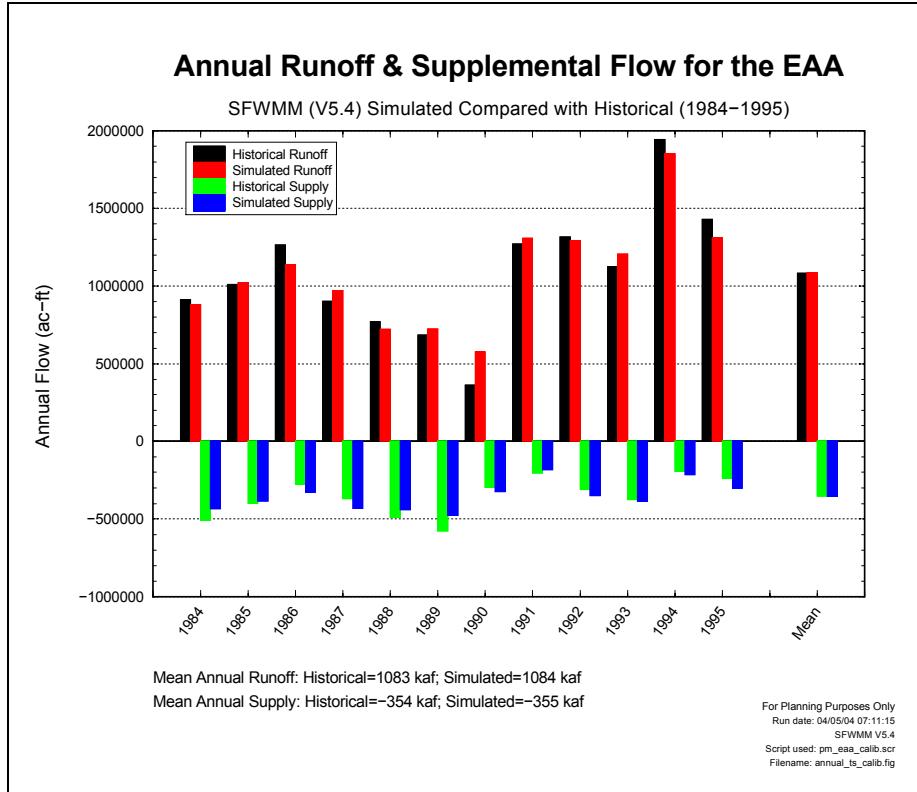


Figure 4.1.2.1 Calibrated Annual Runoff and Supplemental Flow for the EAA

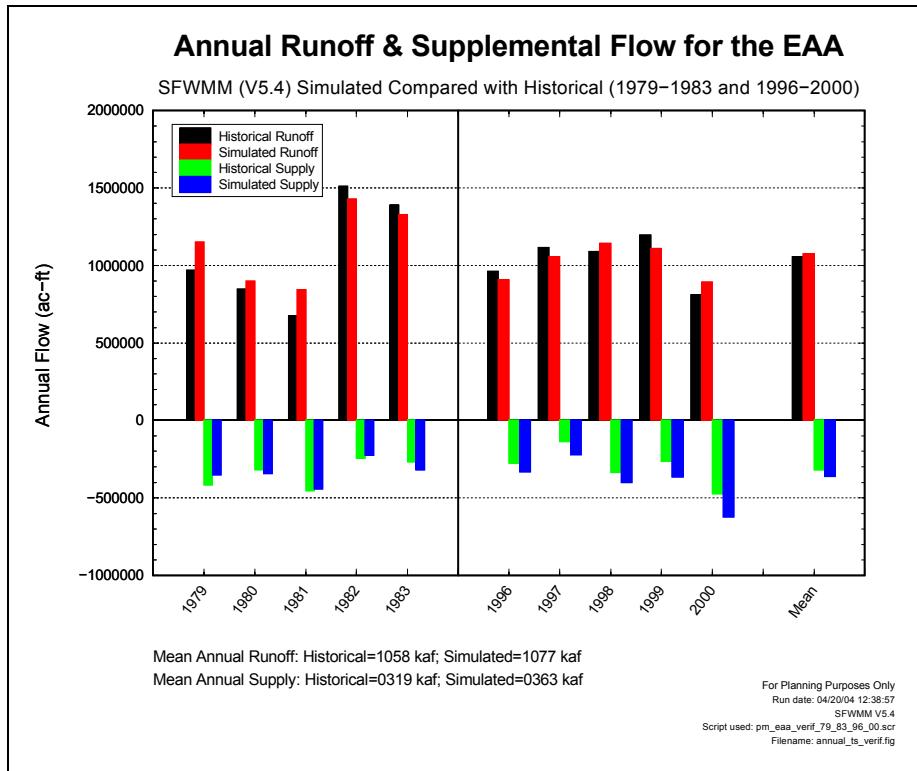


Figure 4.1.2.2 Verified Annual Runoff and Supplemental Flow for the EAA

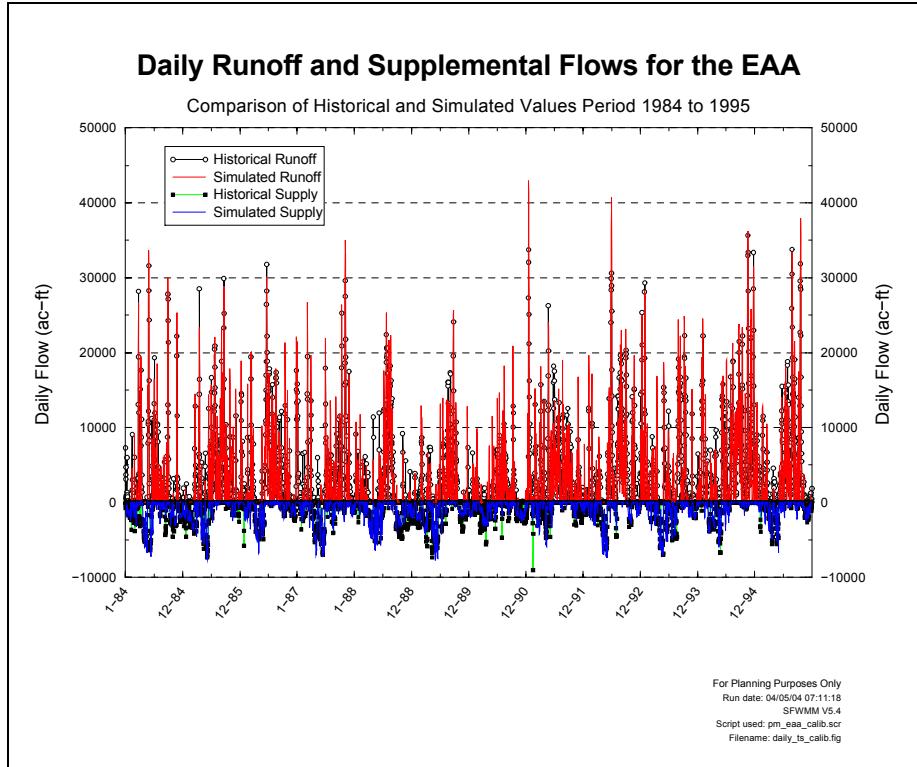


Figure 4.1.2.3 Calibrated Daily Runoff and Supplemental Flows for the EAA

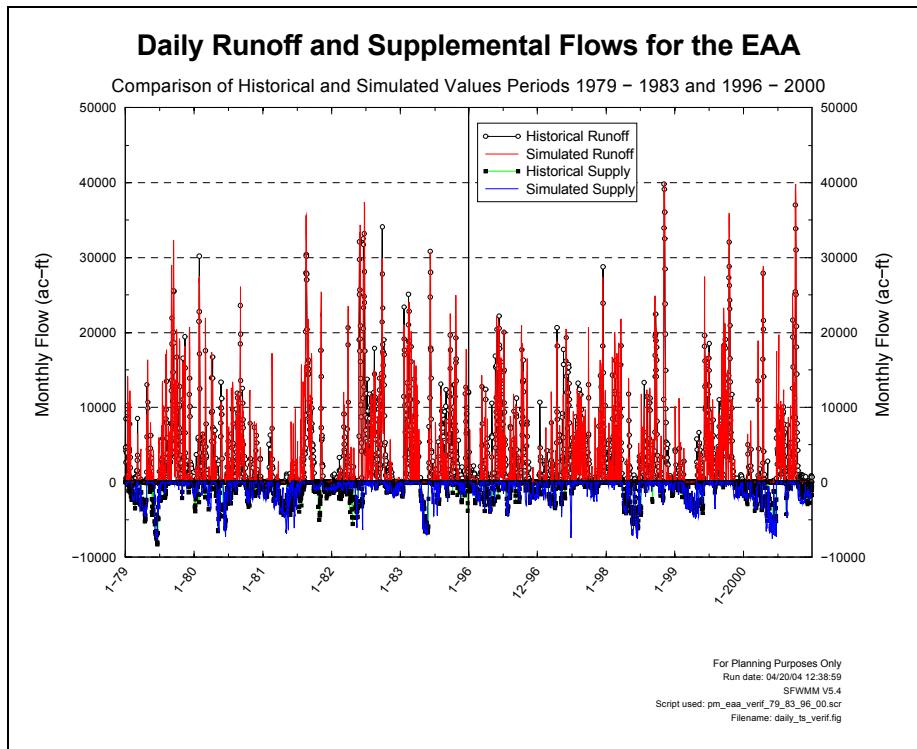


Figure 4.1.2.4 Verified Daily Runoff and Supplemental Flows for the EAA

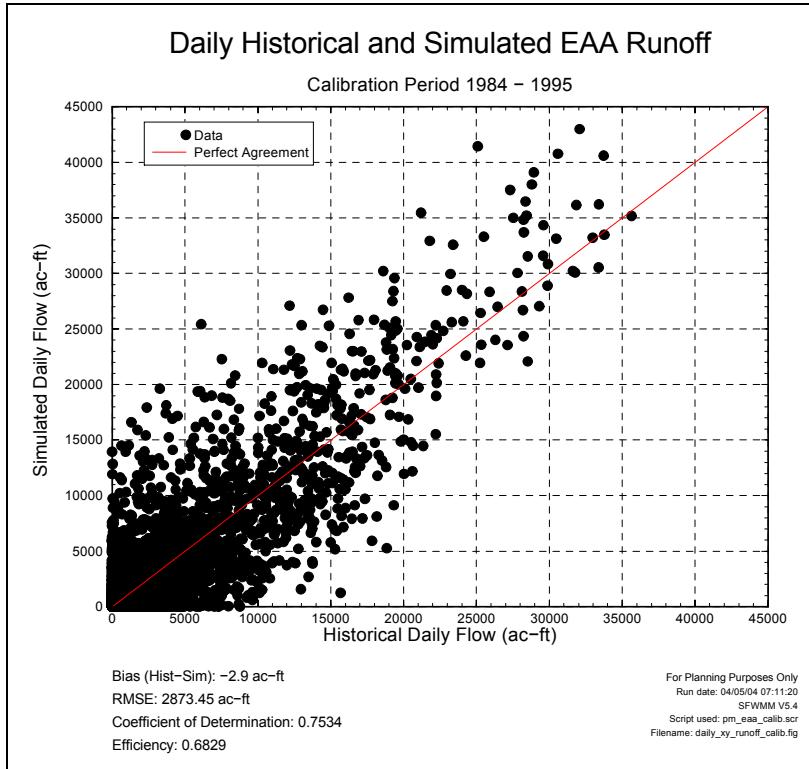


Figure 4.1.2.5 Calibrated Daily Historical and Simulated EAA Runoff

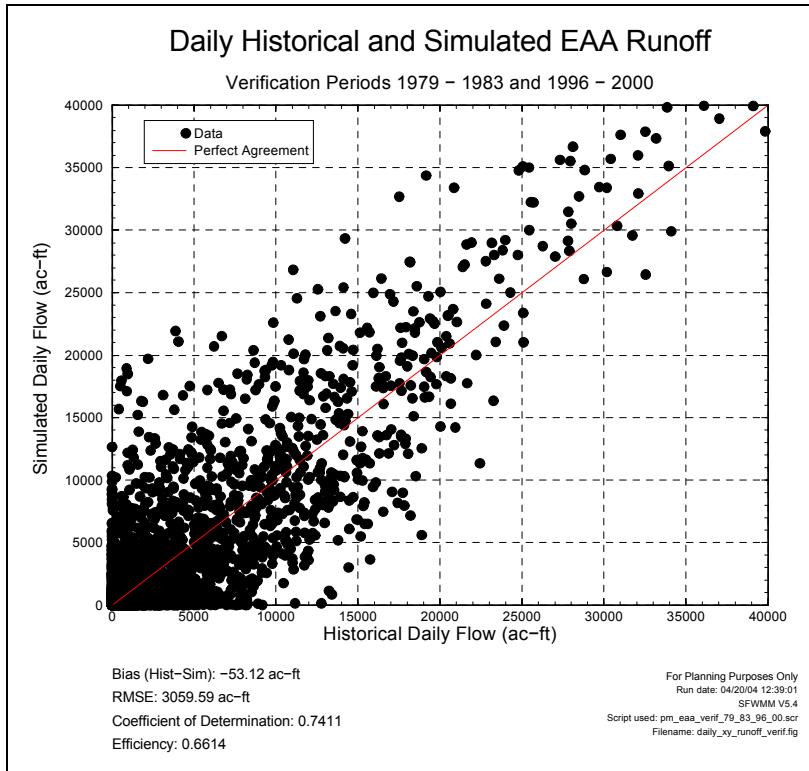


Figure 4.1.2.6 Verified Daily Historical and Simulated EAA Runoff

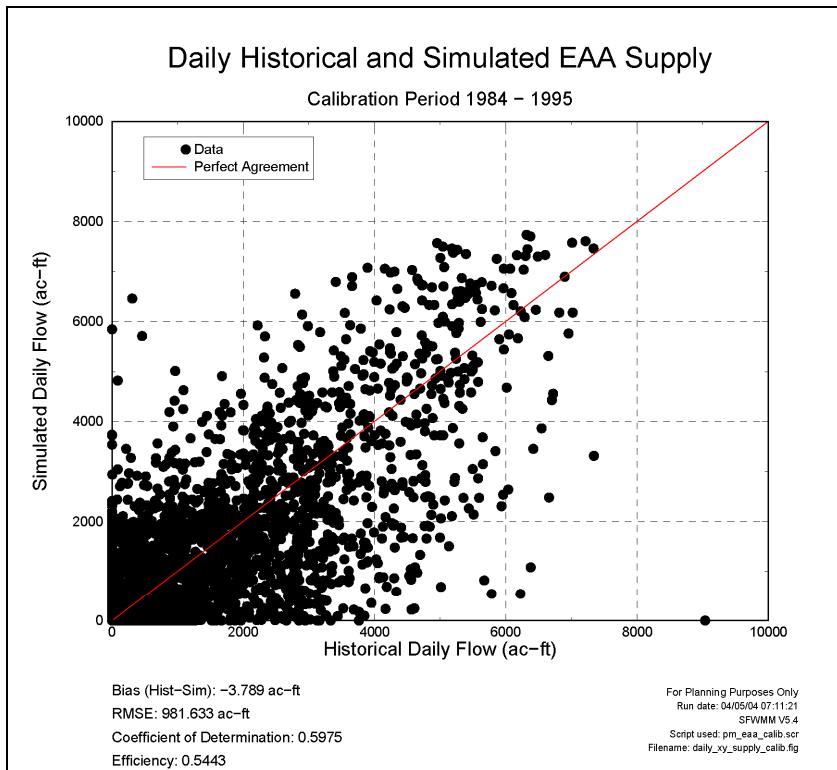


Figure 4.1.2.7 Calibrated Daily Historical and Simulated EAA Supply

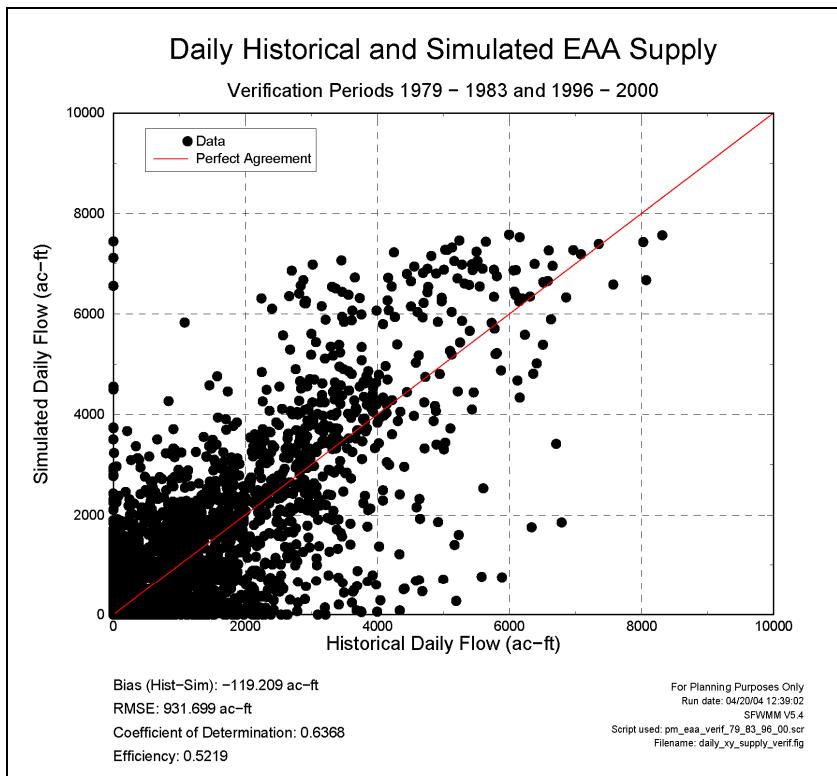


Figure 4.1.2.8 Verified Daily Historical and Simulated EAA Supply

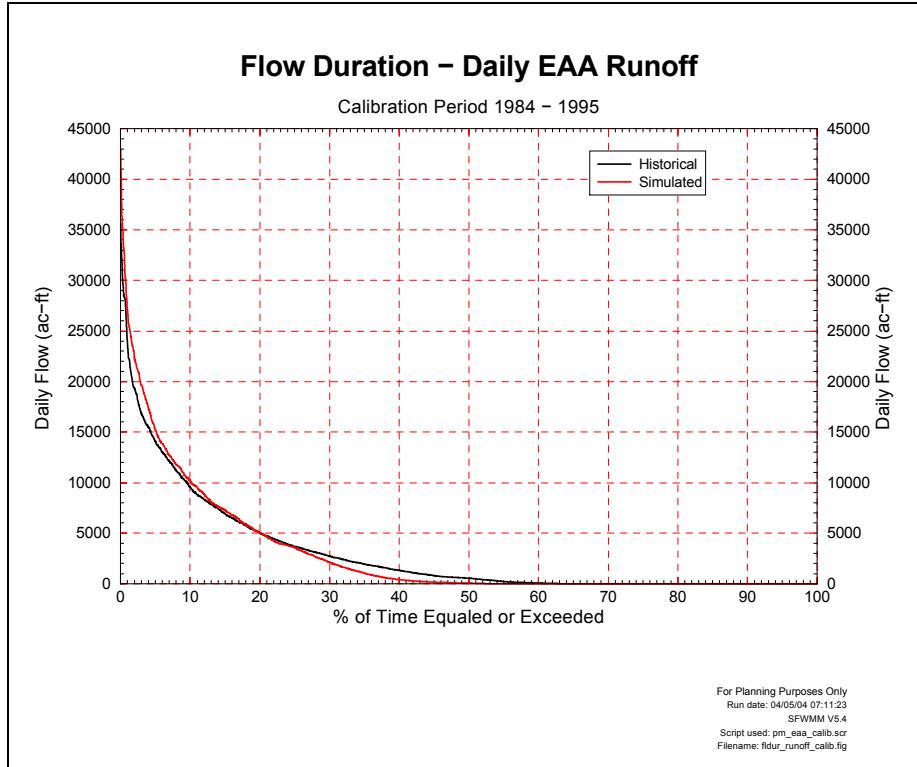


Figure 4.1.2.9 Calibrated Flow Duration – Daily EAA Runoff

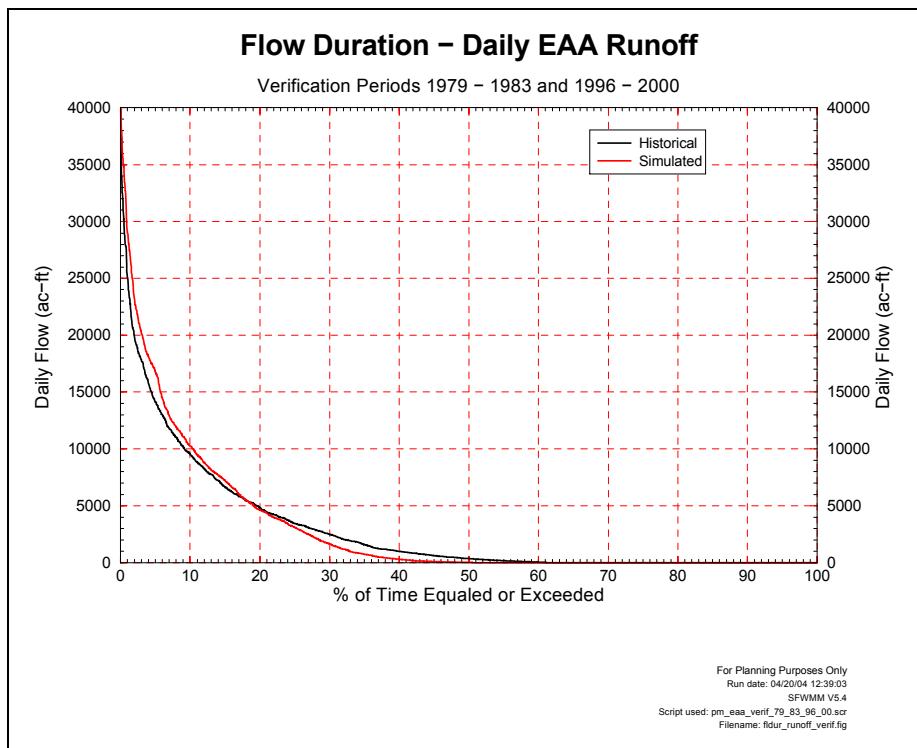


Figure 4.1.2.10 Verified Flow Duration – Daily EAA Runoff

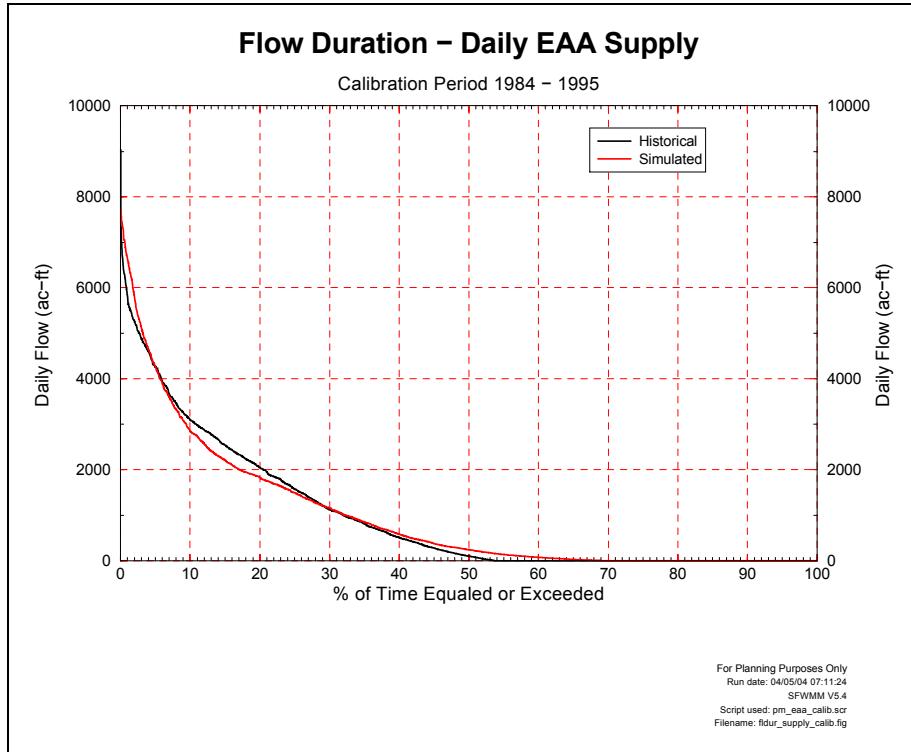


Figure 4.1.2.11 Calibrated Flow Duration – Daily EAA Supply

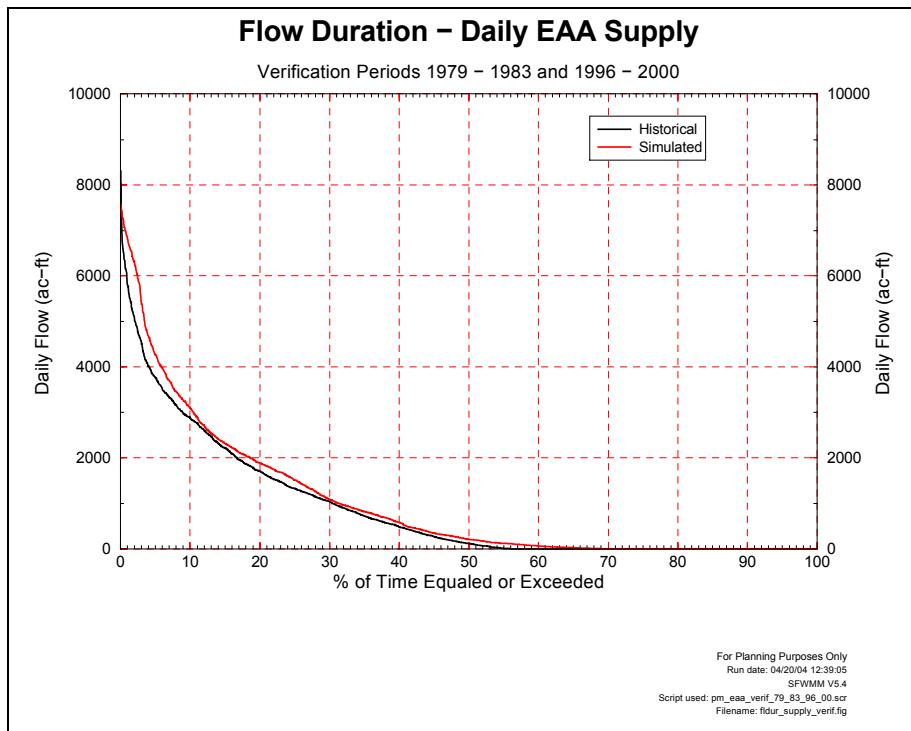


Figure 4.1.2.12 Verified Flow Duration – Daily EAA Supply

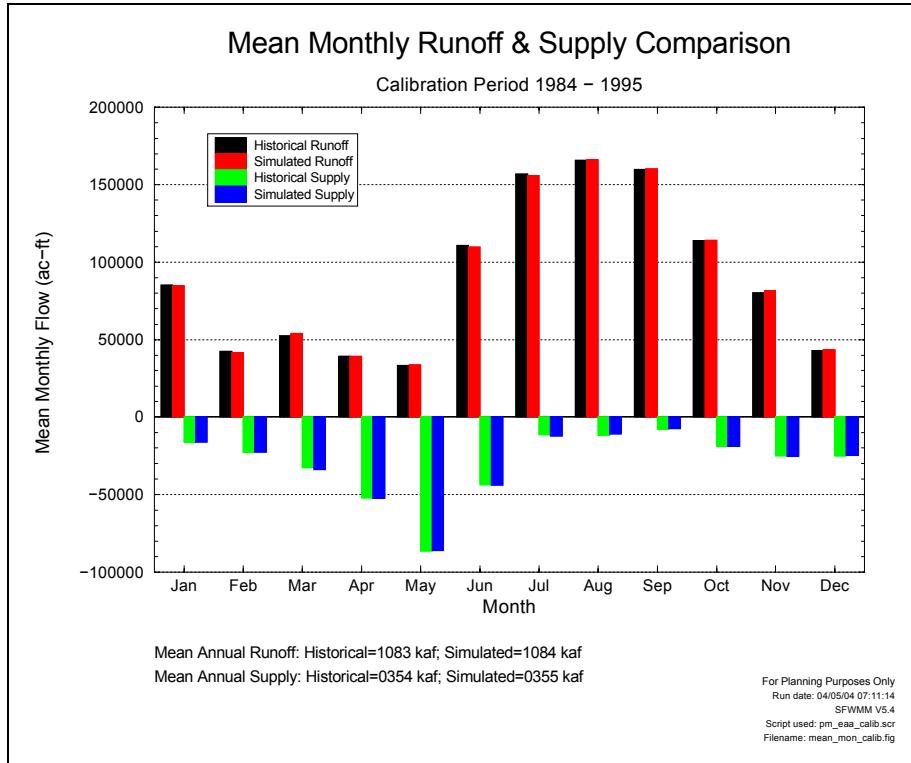


Figure 4.1.2.13 Calibrated Mean Monthly Runoff and Supply Comparison

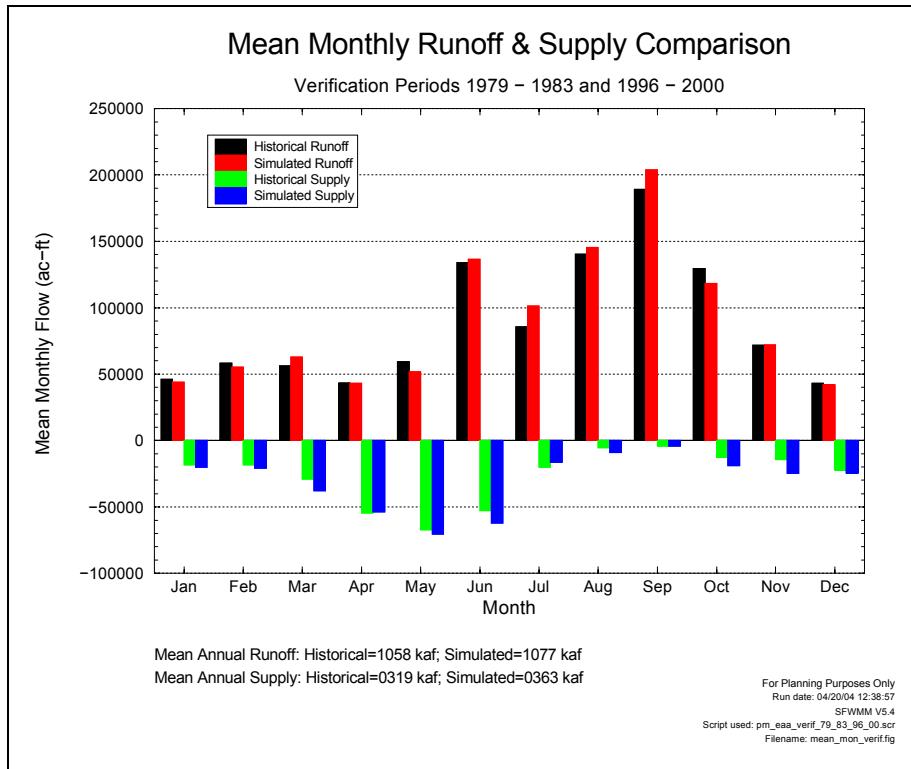


Figure 4.1.2.14 Verified Mean Monthly Runoff and Supply Comparison

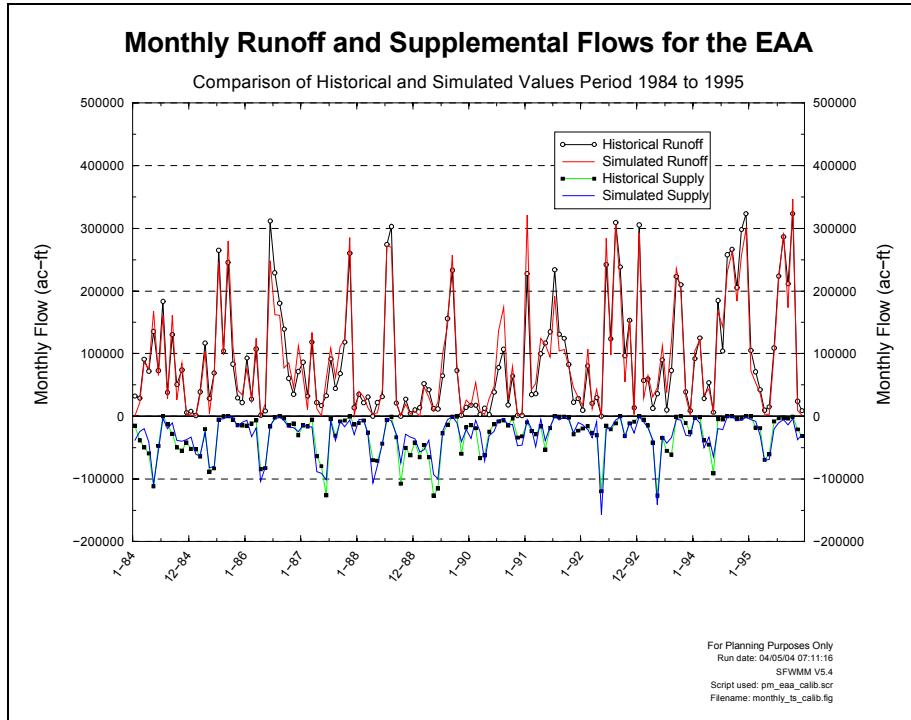


Figure 4.1.2.15 Calibrated Monthly Runoff and Supplemental Flows for the EAA

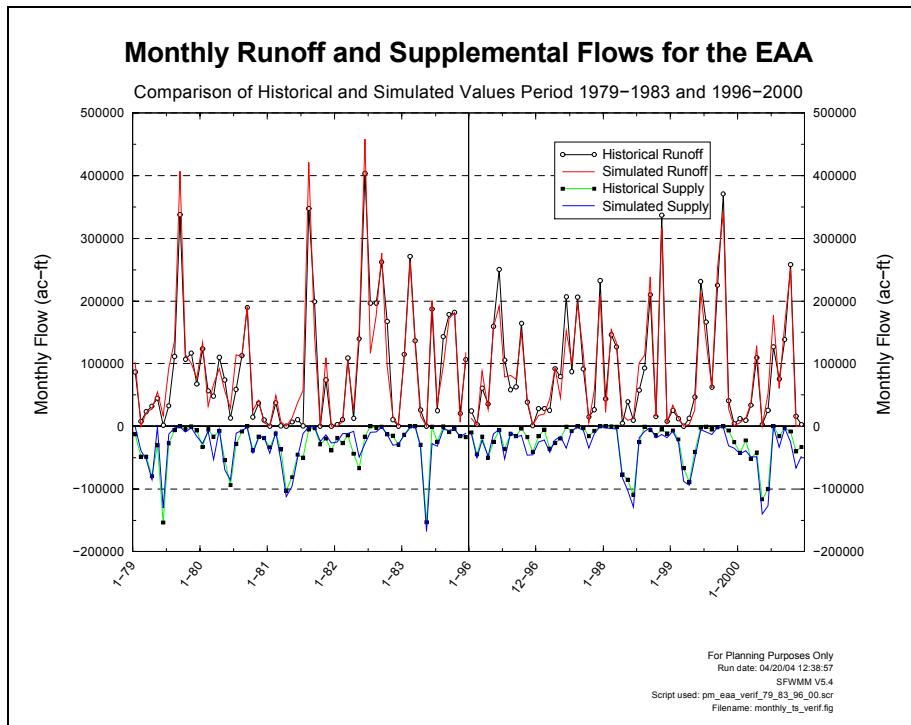


Figure 4.1.2.16 Verified Monthly Runoff and Supplemental Flows for the EAA

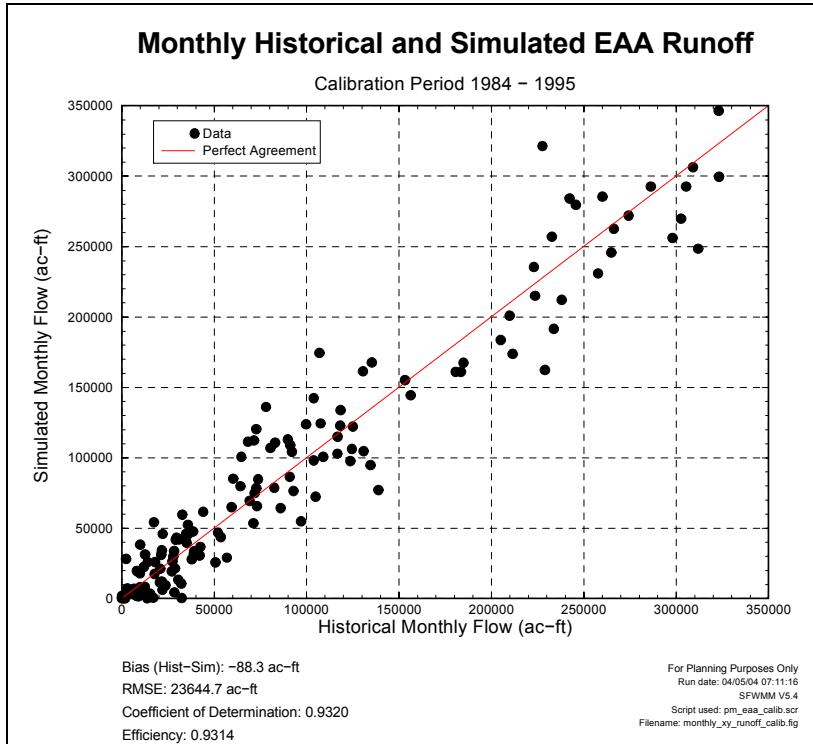


Figure 4.1.2.17 Calibrated Monthly Historical and Simulated EAA Runoff

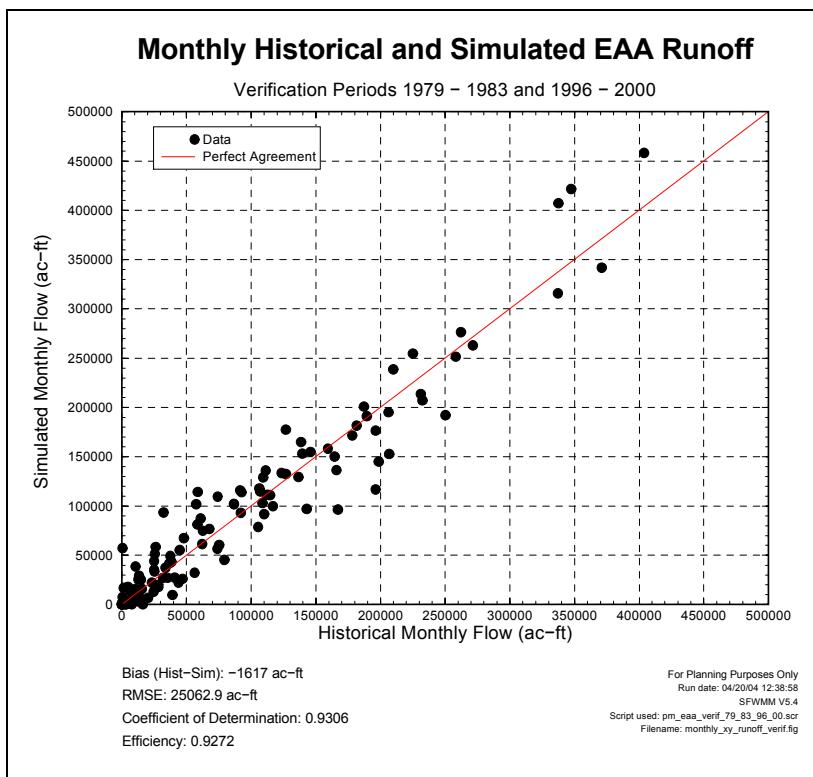


Figure 4.1.2.18 Verified Monthly Historical and Simulated EAA Runoff

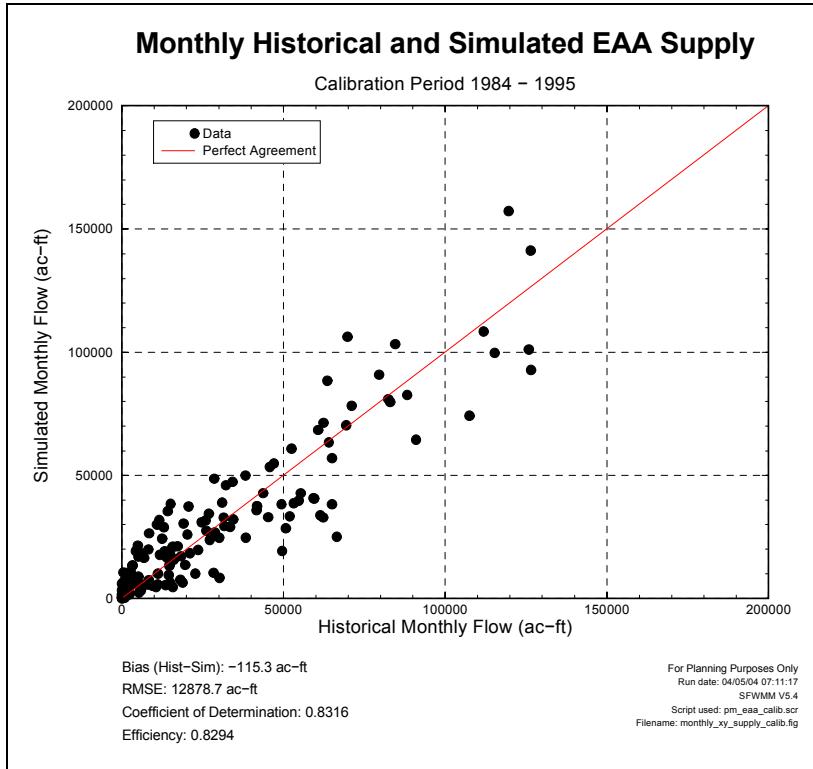


Figure 4.1.2.19 Calibrated Monthly Historical and Simulated EAA Supply

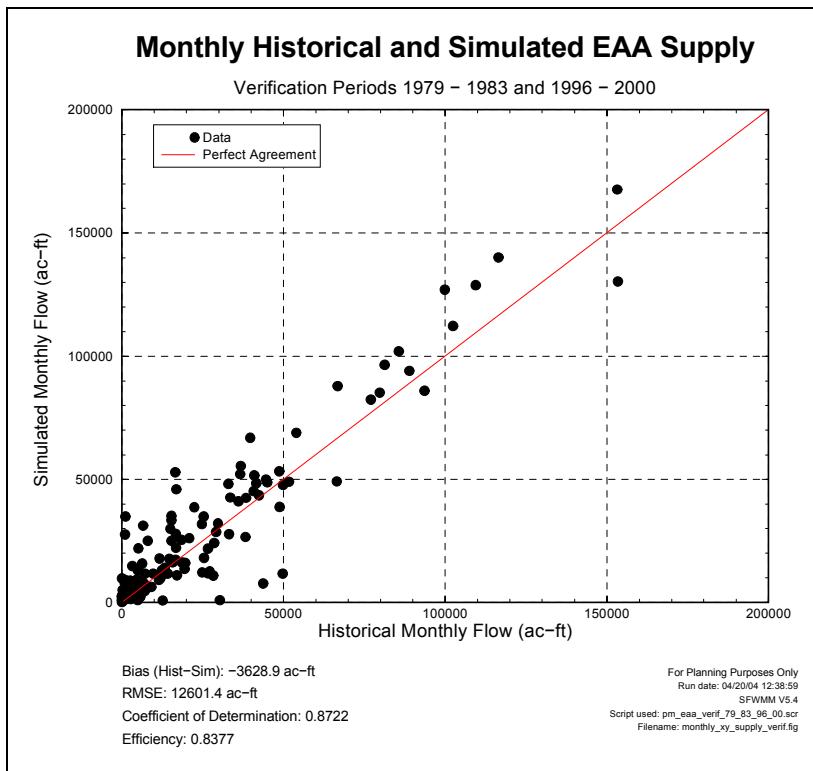


Figure 4.1.2.20 Verified Monthly Historical and Simulated EAA Supply

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